# Observations of C-Band Brightness Temperature from the Hurricane Imaging Radiometer (HIRAD) on board NASA WB-57 during GRIP in Hurricanes Earl And Karl (2010)


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## Hurricane Imaging RADiometer (HIRAD)

**HIRAD Passive Microwave C-Band Radiometer :**

- ***Version 1:*** H-pol at 4, 5, 6 & 6.6 GHz freq for wind speed and rain rate
- ***Version 2:*** H- & V-pol continuum of C-band freq for Ocean Surface Vector Wind (OSVW) & rain rate

**Performance Characteristics:**

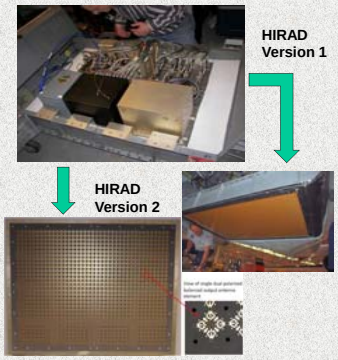
- Earth Incidence angle: 0- 60°,
- Spatial Resolution: 2-5 km,
- Swath: ~70 km for 20 km altitude

**Observational Goals:**

WS: 10 to >85 m/s; RR: 2 to > 100 mm/hr

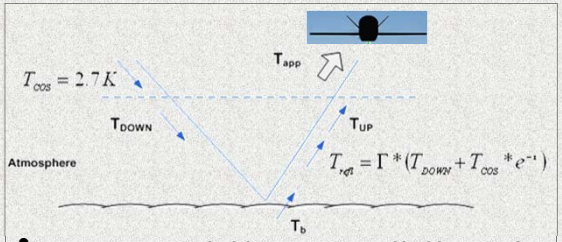
**HIRAD advances:**

- Expands Stepped Frequency Microwave Radiometer (SFMR) coverage from nadir to wide swath
- Eliminates SFMR max wind under-sampling with wide-swath sampling of entire eyewall (instantaneously)
- Uses synthetic thinned array and RFI mitigation technology of Lightweight Rain Radiometer (NASA Instrument Incubator)



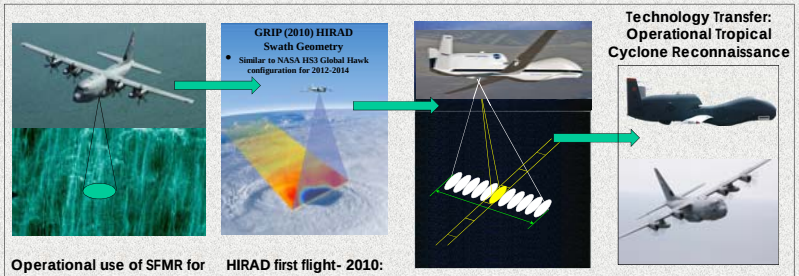

- A continuum of frequencies rather than 4 discrete ones will result in more accurate wind speed retrievals and with dual-polarization: wind direction retrievals as well (OSVW).
- It will also eliminate wind and rain retrieval ambiguities in gale-force wind regimes.

## HIRAD Physical Principles




- HIRAD measures 'emissivity' over a range of incidence angles and frequencies from ocean surface foam (a function of wind speed) and intervening rain.
- At C-band microwave frequencies (4-6.6 GHz), emissivity from wind-driven foam is invariant with frequency while rainfall emissivity is a strong function of frequency.
- These physical characteristics allow two geophysical variables (wind speed and rain rate) to be derived from emissivity measurements at 4-6 discrete C-band frequencies, an 'over-determined', 'least-squares' problem solvable with conventional mathematical techniques.
- Surface wind speed and rain rate retrievals are derived from empirical correlation of HIRAD measured emissivity at operating incidence angles with co-located GPS dropsonde surface wind observations and accepted functional relations for rain attenuation vs frequency.

## HIRAD Technology Investment Roadmap



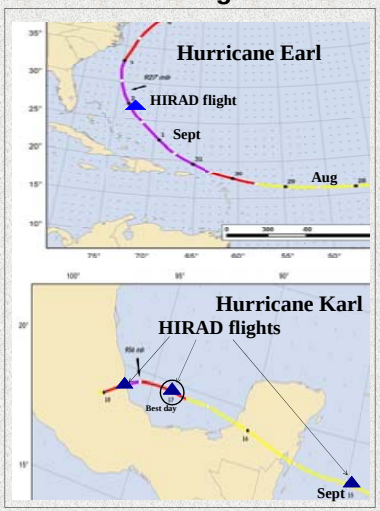

Operational use of SFMR for Ocean Surface Wind Speed and Rain Rate (AF WC-130J, NOAA WP-3D)

HIRAD first flight- 2010: NASA GRIP- Genesis and Rapid Intensification Project (WB-57)

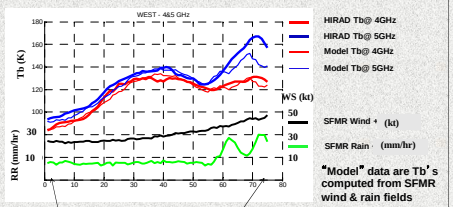
Next up: NASA Hurricane and Severe Storm Sentinel (HS3) mission 2012-14 (Global Hawk)

Improved Hurricane Ocean Surface Vector Winds and Rain Rate

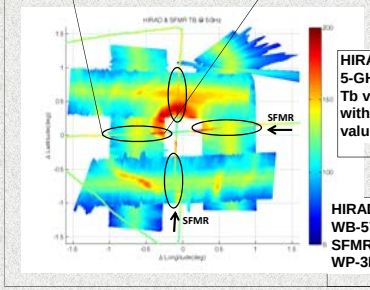
## Earl and Karl Storm Tracks: HIRAD WB-57 Flight Locations




## Earl Flight: 1-2 Sept 2010



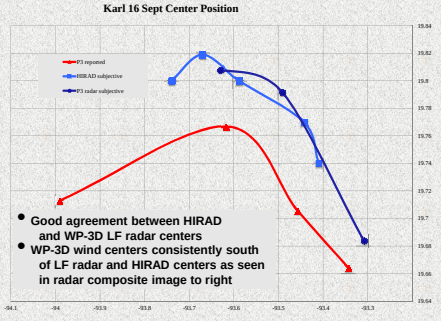

"Model" data are Tb's computed from SFMR wind & rain fields



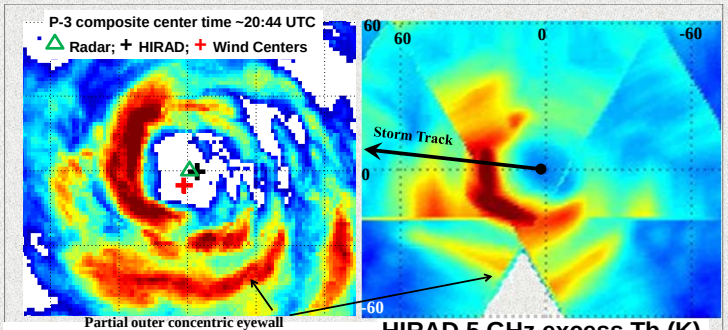

HIRAD 4- and 5-GHz observed Tb values agree with SFMR Tb values

HIRAD obs from WB-57 at 20-km; SFMR obs from WP-3D at 3 km

## Karl 16 Sept 2010



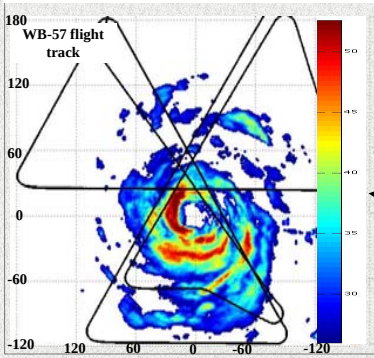

- Good agreement between HIRAD and WP-3D LF radar centers
- WP-3D wind centers consistently south of LF radar and HIRAD centers as seen in radar composite image to right

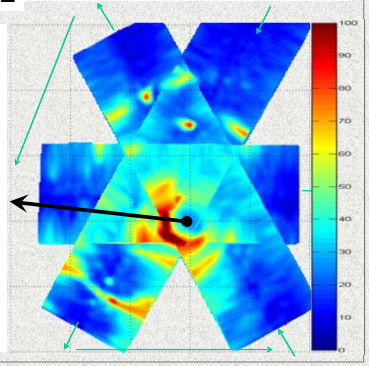



**Key features of radar and HIRAD comparison (right):**

1) Eyewall dBZ and HIRAD Tb maxima are located in left-front quadrant. This, together with open eyewall in right-rear quadrant, suggest easterly environmental shear.

2) Partial outer concentric eyewall is suggested equally well in radar and HIRAD images, as is outer principal rainband.



**HIRAD GRIP Calibration Challenges**

- Rain rate and wind speed retrievals to be based on three calibrated frequencies: 5 GHz $T_b$ (Microwave Brightness Temps) have been successfully produced Calibration of other 2 channels is in progress; completion within 3 months
- HIRAD calibration issues and mitigation for HS3:
  - Calibration uses internal reference blackbody targets and noise diodes
  - Calibration algorithm depends on reference $T_b$: uncorrected instrument temperature dependence found during GRIP flights (+/-25º C)
  - Temperature correction algorithm being developed for GRIP (requires additional instrument characterization testing)
  - Thermal control subsystem has been upgraded for HS3 to minimize instrument temperature fluctuations